

# Limits to agricultural growth in the Sistan Closed Inland Delta, Iran

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**Abstract** The Sistan Delta in Iran is located at the end of a closed basin with nearly 100% of the supply coming from Afghanistan. This supply is supporting irrigated agriculture in the area and is the source for the lake system around the delta. These Hamoun lakes are ecological very valuable wetlands; a number of them are registered as Ramsar sites. The Iranian government tries to improve the living conditions of the people in the area, among others by providing infrastructure for irrigated agriculture. Further development of the irrigated area will mean less water for the Hamouns with resulting lower average water coverage of the lakes. This will not only endanger the ecosystem that the Hamouns support but also the livelihoods of the people that depend on the goods and services that the lakes provide. This paper describes a study that has been carried out to support decision making on potential development schemes in the delta. The non-availability of data from Afghanistan requires the development of various tools and the use of remote sensing techniques to enable to make estimates for the river flow that Iran can expect from Afghanistan. An IWRM approach has been used for the balancing of interests involved. Some preliminary conclusions are described.

**Keywords** Integrated water resources management · Irrigation · Remote sensing · Wetlands

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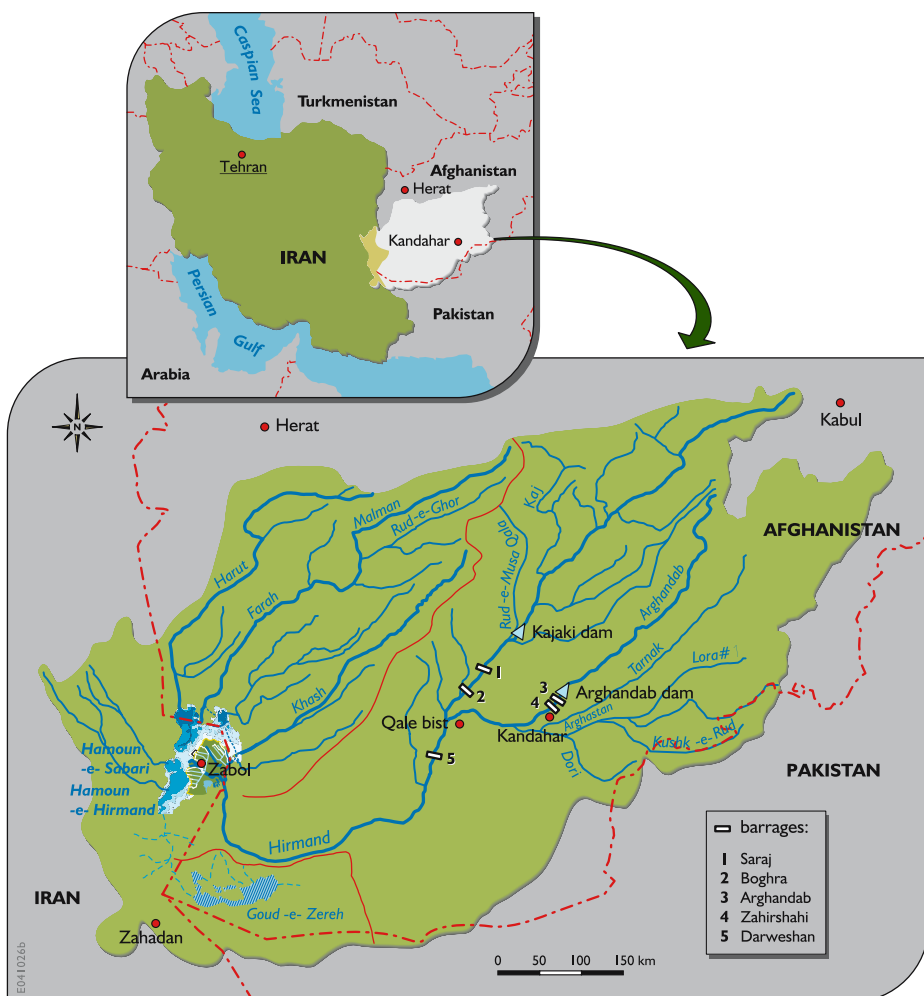
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## Introduction

Wetlands in semi-arid and arid regions are usually fed by rivers, which bring the water from remote areas, e.g. the Mesopotamian Marshes or the Okavango Delta. People living in these arid regions heavily depend on the discharge of the rivers and the water stored in the wetlands: their agriculture is irrigation based since there is no sufficient rainfall to support production. This is the case of the Sistan basin too.

### The study area

The Sistan inland delta is a densely populated enclave in the south-eastern part of Iran at the lower end of the Hirmand River (Fig. 1). In Afghanistan this river is called the Helmand. The entire contributing basin is about 200,000 km<sup>2</sup> and is largely located in Afghanistan. The Iranian part, the delta plain (ca. 2,500 km<sup>2</sup>) and part of the surrounding wetlands



**Fig. 1** Contributing river basins Sistan inland Delta

system (ca. 5,000 km<sup>2</sup>), covers less than 5% of the total basin area. The river system is fed by rains and snowmelt in the Hindu-Kush Mountains and discharges into an inland depression which, when sufficient water is available, forms the Hamoun Lakes. These lakes are one of the main and most valuable aquatic ecosystems in Iran. About half of the area is registered in the Ramsar and UNESCO Biosphere Reserve Conventions. A unique feature of the lakes is that they are fresh or brackish, despite that they are seemingly at the end of a closed basin. Actually, they are not the end. During periods of very high flows the lakes spill via the Shile River into the Goud-e-Zereh. This 'flushing' happens on average each 8–11 years. The Goud-e-Zereh is the real terminal lake of the basin and is very saline.

The Sistan inland delta has a population of some 400,000 people on the Iranian side, whilst only a few ten thousands live on the Afghan side. The economy is strongly dependent on agriculture and the goods and services provided by the wetlands. The irrigation system of about 120,000 ha has recently been rehabilitated. Three reservoirs (Chahnimeh) have been constructed for public water supply with a fourth reservoir under preparation. Details on the Sistan delta and the Hamoun lakes are given in Fig. 2.

The Sistan Delta has a very hot and dry climate. In summer the temperature exceeds 50°C. Rainfall is about 60 mm/year and occurs only in autumn and winter. The open water evaporation is very high and is estimated at 3200 mm/year. Some local sources even claim amounts up to 5000 mm/year. Strong winds are an important reason for this high evaporation. In summer, a phenomenon occurs that is called the '120 days wind' with prevailing wind speeds of nearly 10 m/s (Arasteh et al. 2007).

### Sustainability issues

The socioeconomic and ecological sustainability of the area is a major issue. There are several reasons for this. First of all the potential of the area for socioeconomic developments is limited. Further growth of the traditional activities such as agriculture and the use of the wetlands (fishing, reed cutting and bird catching) is severely constrained by a lack of reliable water supply and the limited carrying capacity of the natural system. The high increase in population (natural and through migration from Afghanistan) has caused a very high pressure on the system and over-use and mismanagement have resulted in a collapse of the natural system. Intensified cattle grazing and the introduction of exotic herbivorous fish have destroyed the regeneration capacity of the reeds after dry years. This is aggravated by the highly dynamic river flow with strong yearly fluctuations as well as with wet and dry periods lasting several years (Fig. 3). The wet period between 1989 and 1993 caused considerable flooding damage in the area. The dry period between 2000 and 2005 resulted in the Hamouns falling completely dry, turning them into a desert and wiping out the water related ecosystem in the area. Mismanagement of the system (in particular the introduction of grass carp that destroyed the reed fields) has worsened the situation and has made it more difficult for the system to recover after the dry period.

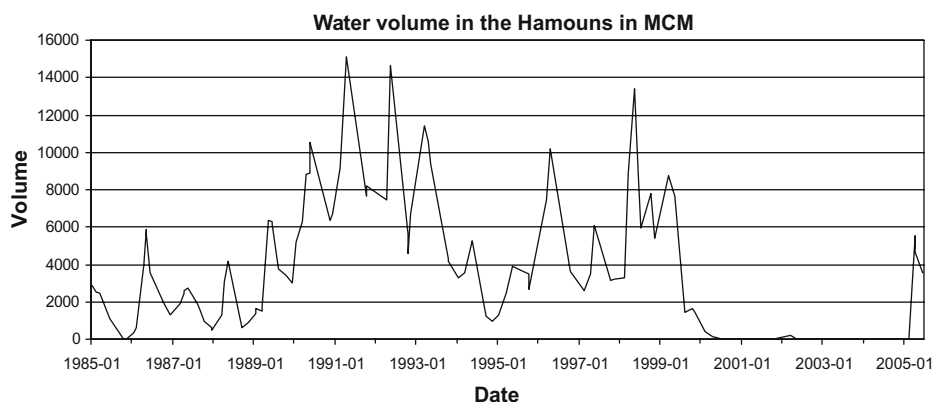
Another threat to the sustainability of the area is the potential developments in Afghanistan. Nearly all water for the Sistan delta originates from Afghanistan. Many plans exist in Afghanistan to develop the water resources upstream (reservoirs, irrigation systems, drinking water withdrawals, etc.). No reliable information exists on the status of these developments but it is highly likely that some if not all of these developments will take place sooner or later. The existing agreement between Afghanistan and Iran on the Hirmand is rather limited in scope and only guarantees Iran a minimal amount of water sufficient for drinking water purposes.



**Fig. 2** Overview map of the Sistan Inland Delta

### Objective of the study

The Iranian government is trying hard to improve the living conditions of the people in the area, in particular by providing employment and improving the health situation of the people. The available water resources is a constraint for this development, in particular for the planned extension of irrigated agriculture. The objective of the study was to quantify the supply and potential demand, design alternative development strategies while protecting the ecological values of the wetlands. This paper focuses on the potential development of agriculture in the area in the mirror of water availability and balancing of interests needed to take decisions in this respect. A main part of the study consisted of the development of tools to predict the water supply and to quantify the impacts of possible developments on the Hamouns. The study was jointly carried out by a Netherlands Consortium headed by Delft Hydraulics and the Water Research Institute (WRI) of Iran. Preliminary results are



**Fig. 3** Water volume in the Hamouns in MCM in period 1985–2005

described in Delft Hydraulic and WRI (2006). The client of the study was the Sistan-Baluchestan Regional Water Authority (SBWRA).

### Developing the area – the challenges

The main employment sectors in the Sistan delta are agriculture-fisheries (38%) and services (54%). The industrial sector is small (6%). Unemployment in the area is high: reliable statistics are lacking but indications point in the direction of about 50%. The very skewed population structure (about 50% of the population is below 20 years) will further degrade the situation. The Sistan Delta is a very political sensitive area bordering Afghanistan and Pakistan (Baluchestan) so the Iranian government tries to stabilize the area by investing in its socioeconomic development. An extensive system for drinking water supply has been constructed providing a near 100% coverage for urban and rural population. Possibilities to increase the industrial sector are constrained by the geographical location of the area in relation to potential markets of the products. Hence, it is not surprising that solutions are sought in agriculture. Already 120,000 ha irrigated agriculture have been developed and there are plans for another 125,000 ha. However, agricultural development is severely constrained by the harsh climatic conditions and the variable water supply. Moreover, the withdrawal of the water for irrigation will be at the expense of the Hamouns and their ecosystems. The variable river flow will require the development of storage reservoirs to support the irrigation. The existing Chahnimeh reservoirs (see Fig. 2) are only for drinking water but could be extended to serve irrigation as well. The total live storage capacity of all four Chahnimeh reservoirs together will be 950 MCM/year.

### The water balance

The first question is if the available water supply will be sufficient to support these developments. Table 1 shows a simplified average annual water balance for the delta for the present situation. The total available water is 5,935 MCM/year. The demand for the present 120,000 ha irrigated agriculture is 2,069 MCM/year. Due the variability of river flow and presently non-existent storage capacity for irrigation the actual supply is 1,169 MCM. If the irrigation area is increased this has to be done in combination with the development of

**Table 1** Average annual water balance Sistan Delta (in MCM/yr)

Inflow <sup>a</sup>		Outflow	
Hirmand	3,908	Agriculture (120,000 ha) <sup>b</sup>	1,161
Farah	1,512	Public water supply	34
Khash	455	Hamouns evaporation	4,378
Precipitation	60	Chahnimeh evaporation	124
		Outflow to Shile	238
Total	5,935	Total	5,935

<sup>a</sup> Derived from hydrological records of the period 1947–1971 at stations close to the inflow into the Hamoun system (resp. Char Burjak, Dilram and Farah) which are downstream of the major irrigation systems in Afghanistan

<sup>b</sup> Actual supply, the full demand of the 120,000 ha is much higher (2,069 MCM/yr); efficiency losses and drainage water are included as these do not return to the system (evaporate also); it includes also a small allocation to irrigation areas in Afghanistan

surface water storage schemes. Groundwater storage is not possible because of the geo-hydrological situation.

### The Hamouns

The second question is what the effects of this additional agricultural development will have on the Hamouns. From a water quality point of view measures are taken, which take care that the pollution (fertilizers, pesticides) resulting from agriculture will not reach the lakes. A major part of the drainage water is collected in special basins from where the water evaporates. Hence, the main impact will be a reduction in the evaporation of the lakes and a reduction of the outflow to the Shile. The Hamouns are at present by far the largest ‘water user’ of the system evaporating 4,378 MCM/year. Reducing the evaporation of the Hamouns is synonymous with reducing the average water cover area of the lakes and with that their potential to support the ecology depending on that water. In principle the relation between agricultural development and water cover is quite simple. An open water evaporation of 3000 mm/year means that each 100 MCM/year additional withdrawal for irrigation will reduce the average lake area by 33 km<sup>2</sup> which is about 2.5% of the present average lake area. Hence, a full supply of the present 120,000 ha irrigation area with 2,069 MCM/year could reduce the average lake area with about 50%. In reality this relation is much more complex since the system consists of 3 parts, which are functioning relatively separately with their own highly variable supply. Because of this, the water cover of the lakes is very dynamic too. In dry periods the lakes can fall completely dry as has been the case in the period 2000–2005, temporary creating a desert-like environment. When the lakes start filling after a rainy period, the ecology recovers. Reed starts growing again and birds and fish return. This process has been going on for ages and proves that the system can absorb to some extent these natural dynamics. The question is if it also can absorb a more continuous decrease of inflow. A reduced water cover of the Hamouns will not only hurt the ecological functioning of the lake. Also the livelihoods of the people that depend on the products and services of this system are endangered.

The Hamouns provide goods and services for all people in the Sistan Delta. Four groups of values were identified for these people: income and food, health, perception and experience, and independence and social structure. A survey conducted among the stakeholders revealed that all people in the area (close *and* further away from the Hamouns,

rural *and* urban) give great importance to these values with all of them agreeing (100% score) on the health effects involved. The combination of strong winds and water cover provide a kind of natural air conditioning while the same strong winds with empty Hamouns result in severe sand storms in the area. The overall conclusion of the survey was that all people in the delta considered the wetlands as very important for their lives and, hence, not only just the farmers and fishermen who are directly dependent on the lakes for their income.

## Approach and tools

### IWRM – balancing the interests

From the above it has become clear that a major issue for the study was to balance the benefits from irrigated agriculture with the values provided by the Hamouns. Integrated water resources management (IWRM) addresses, among others, this balancing of interests and has been applied as the basic approach for the study. IWRM is a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems (GWP 2000). The systems analysis approach of IWRM takes care of a structured analysis process as well as the quantification of the aspects that need to be balanced. For the quantification a RIBASIM application for the Sistan delta has been developed. RIBASIM is a generic computer package for river basin allocation issues (Delft Hydraulics 2005). The analysis process follows the framework of analysis as described in Loucks and Van Beek (2005).

### Predicting the supply

A crucial and at the same time one of the most unknown variable in determining the sustainability of the system is the supply of water from the Hindu-Kush Mountains. Existing data is limited and recent data is not available at all in Iran. More accurate data is needed to evaluate the feasibility of the development plans in Iran as well as to predict the long term discharge (one-year predictions e.g. for the determination of cropping areas and patterns) as well as the short term discharge (days till weeks for operational purposes, e.g. for flood warning and the operation of intakes). A complicating factor in predicting the supply is the unknown developments in the upstream areas. At present no data or other information is made available by Afghanistan to Iran. To cope with this situation a model system was developed that combined medium range weather forecasts with a grid-based hydrological model HBV (Bergström and Forsman 1973) modeled in PC-Raster and a river basin model for the river system in Afghanistan (based on RIBASIM).

### Using remote sensing and GIS methods

Given the data scarcity involved in this case, both physically (limited monitoring in Afghanistan and Iran) as well as politically (the cooperation between Iran and Afghanistan on the Sistan wetlands just started recently) the use of earth observation data was very important in the study. The following three examples are given here.

### *Snow cover mapping using satellite images*

The hydrological HBV module of the river runoff forecast model uses the weather forecasts from the European Centre for Medium Range Weather Forecast (ECMWF). The actual rain (and snow) fall will of course deviate from the estimate. Moreover, the grid size of this forecast is rather coarse. An important variable that the HBV model calculates is the snow cover in Afghanistan, which determines to a large extent the water availability for the Sistan Delta. By using satellite images (Salomonson and Appel 2004), the calculated snow cover of the HBV model can be corrected, improving the accuracy of the forecast model.

For model calibration purposes, time series of snow cover maps from the 1990's were generated from NOAA AVHRR data. An automated procedure masked the cloudy areas from each selected archived image and then – using the altitude of the visible snow line in the cloud-free parts of the Hindu-Kush Mountains – created a snow cover map. This map was then used for improving the HBV model.

For operational river runoff forecast, 8-day snow cover products calculated from MODIS images (Hall et al. 2002) are to be used, since these products are readily and freely available since the first years of this millennium via the World Wide Web.

### *Estimation of cropping area in Afghanistan*

No reliable data is available on the actual cropped area in Afghanistan. For the identification of irrigated areas in arid regions such as Afghanistan an approximate solution is to map vegetation in the time of the year when natural vegetation is not green, leaving the irrigated areas to show up. This can be done by the normalized differential vegetation index (NDVI) which is calculated from the red and infrared bands of satellite images. Use is made of the MODIS sensor of the Terra and Aqua satellites that provides daily data and which are almost real-time accessible through internet (NASA 2005). For future conditions scenarios were developed by using information from FAO (1997) and Favre and Kamal (2004).

### *Inundation and vegetation cover of Hamouns*

To increase our understanding of the hydrological and ecological functioning of the Hamoun systems, information was needed on the dynamics of the inundation and vegetation cover of the Hamouns. This was achieved by using Landsat and NOAA AVHRR data with some additional information retrieved from quick looks of IRS and Landsat. The results are described in Vekerdy et al. (2006).

## **Analysis and results**

The analysis started with an inception phase in which – in interaction with the stakeholders – a joint problem statement and the development objectives for the area were formulated. The problem statement and objectives formed the base on which the criteria/indicators were determined that the stakeholders want to use in the evaluation of alternative development strategies. The indicators have a direct link with the objectives and include, among others:

- Reliability drinking of water supply (%)
- Supply/demand ratio of agriculture (%)
- Agricultural production (tons/year)



- Hamoun ‘production’ (fish, birds, reeds, in tons/year)
- Ecology of Hamouns
  - average area (ha)
  - flushing (frequency)
  - ecosystem condition (% of reference)
- Health
  - frequency of drying out of Hamoun-e-Saberi (causing sand storms)
- Income stakeholders
  - farmers – irrigation (frequency of years with < 50% reference income)
  - Hamoun users (same)

As reference for the income of the stakeholders and the ecosystem condition the situation in the decade 1970–1980 has been selected as this period was considered to be good, even though also in this period dry years occurred. Nature and people have adapted to the variability in water supply and they can survive ‘normal’ dry years. The indicators that use this reference express how much will be deviated from this.

The next step was to develop scenarios and strategies. A clear distinction was made between ‘*scenarios*’ that represent external developments that cannot be influenced by the decision makers involved in the water resources in the Sistan area and ‘*strategies*’ that include the interventions that these people can actually decide upon. The main scenario elements were population growth in the area and upstream developments in Afghanistan, more or less determining the boundary conditions with respect to demand and supply respectively. Strategy elements included supply oriented measures (such as additional reservoir capacity and the operation of the reservoirs), demand oriented measures (in particular related to agriculture), ecology oriented measures (legislation and enforcement, landscaping the Hamouns and Chahnimeh reservoirs to make them more suitable for ecology, etc.) and the increase/decrease of the area of irrigated agriculture.

The actual analysis process is still going on and is carried out in close cooperation with the stakeholders. Reference is made to the full documentation of the project that will be prepared by WRI and SBWRA. Below only the specific issue of agricultural growth will be described. The base case was the present situation: 120,000 ha irrigated area with only 3 Chahnimeh reservoirs to be used for public water supply only. The following agriculture-related strategies were developed:

- Strategy 1 the construction of Chahnimeh-4, to be used for public water supply only
- Strategy 2 same as strategy 1 but with allowed use of Chahnimeh-4 for irrigation also
- Strategy 3 an increase of the present irrigation area of 120,000 ha with an additional 125,000 ha, no use to be made of the Chahnimeh reservoirs for irrigation
- Strategy 4 same as strategy 3 but will Chahnimeh-4 and allowed use for irrigation
- Strategy 5 a decrease in irrigation area from the present 120,000 ha to 21.000 ha (in order to see the effects on the Hamouns)

All these strategies assume that the Hamouns are managed well and no over-exploitation of the natural resources takes place. As external scenario, the present situation in Afghanistan is assumed which includes the Kajaki and Arghandab reservoirs and about 240,000 ha irrigation. In this scenario, the average inflow from Afghanistan will be 5,795 MCM/year. To get some idea about the effects of upstream developments the base case is also evaluated for a scenario in which major upstream developments in Afghanistan will take place and the available water for Iran will reduce to about 3,257 MCM/year.

**Table 2** Score card of alternative agricultural development strategies

Scorecard IWRM Sistan Inland Delta										
Scenario 1			Scenario 2							
Criteria	Unit	Target	Base case		1 Chahmimch 4	2 Chahmimch 4 for irrigation	3 Increase irrigated area	4 Incr. irr. with use Chah. 4	5 Decrease irrigated area	Base case
<b>General information (on case)</b>										
Irrigated area in Sistan	Ha	–	120,000	120,000	120,000	120,000	245,000	245,000	21,000	120,000
Average inflow from Afghanistan	MCM/yr	–	5875	5875	5875	5875	5875	5875	5875	3250
<b>Domestic water supply</b>										
DML raw water supply (Zabol + Zahedan)										
Months supply < demand	%	0	0	0	12.8	0	27.2	0	0	0
<b>Economy – agriculture</b>										
Supply/demand ratio	–	>0.80	0.63	0.53	0.79	0.42	0.45	0.87	0.87	0.31
Agricultural production	ktons/yr		401	340	580	570	634	111	348	348
<b>Economy – Hamouns</b>										
Fish	ktons/yr		20.7	20.7	20.8	20.8	20.8	20.6	20.6	4.8
Birds	ktons/yr		0.78	0.78	0.77	0.71	0.76	0.95	0.95	0.17
Reed	ktons/yr		299	299	296	295	296	303	303	133
<b>Ecology – Hamouns</b>										
Suitable conditions for ecology in Hamouns										
Average maximum area in fall (Oct–Jan)	ha		90,000	89,000	88,000	79,000	85,000	119,000	119,000	45,000
Flushing of Hamouns – Hirmand	T	<8 yr	12.5	12.5	12.5	16.7	25.0	7.1	7.1	16.7
Estimation of ecosystem condition	% of ref		90–100	90–100	90–100	73–87	73–87	90–100	90–100	0–20
<b>Environment/Health</b>										
Return per. in years Saberi <20% of max area	T	0	13	13	13	7	8	50	50	2
<b>Income (return period of years with &lt; 50% of reference income)</b>										
Bird catchers	T		5.44	5.44	4.45	1.69	1.96	9.80	9.80	1.00
Fishermen	T		5.44	5.44	4.45	1.00	1.00	8.17	8.17	1.00
Reed harvesters	T		5.44	5.44	4.45	1.09	1.09	9.80	9.80	1.00
Pastoralists	T		5.44	5.44	4.45	1.69	1.96	4.90	4.90	1.00
Field cultivators near Hamoun	T		2.04	1.20	n/a	3.77	4.45	1.00	1.00	1.07
Animal husbanders on farm	T		1.20	1.20	n/a	n/a	n/a	1.00	1.00	1.11
Field cultivators far from Hamoun	T		1.20	1.20	n/a	n/a	n/a	1.00	1.00	1.11

As reference the situation in the 1970s has been selected as a period in which the conditions were considered to be good

$T$  return period =  $1/f$

n/a not applicable; the situation did not occur in the 55 years of the simulation, and hence no return period could be assessed

The impacts of these scenarios in terms of the defined indicators have been calculated by using the RIBASIM model as described above. A (partly reconstructed) time series of 55 years of inflows and climatological conditions (rainfall, evaporation) have been used to determine the average impacts. The average results are given in the score card of Table 2.

The following preliminary conclusions can be drawn from this scorecard.

- **Base case** (present situation). Note the rather low supply/demand ratio for irrigation (0.63) which means that in many years there will be insufficient water available to cultivate the full present irrigation area.
- **Strategy 1** (Chahnimeh 4 constructed). The storage of water for public water supply will, as expected, deteriorate the conditions for agriculture somewhat. The conditions for the Hamouns hardly change.
- **Strategy 2** (Chahnimeh reservoirs also used for irrigation). The agricultural sector clearly benefits from this strategy. At the other hand the reliability of the public water supply system decreased. Optimization of the operation rules of the reservoirs (applying hedging rules) should be able to improve this.
- **Strategy 3** (increase of irrigation area without reservoir use). The agricultural production will increase somewhat compared to strategy 2 but the reliability of the supply drops to a level (0.42) that will be unacceptable for farmers. The ecological conditions of the Hamouns deteriorate clearly. The return period of a dry Hamoun-e-Saberi increases with corresponding dangers for sand storms. Also the return period of flushing of the Hamouns increases (once in 17 years now) which will result in an increase of the salt concentration of the Hamouns.
- **Strategy 4** (as strategy 3 but now with allowed use of the Chahnimeh reservoirs for irrigation). This strategy improves the performance of the agricultural sector somewhat but the reliability of the supply remains too low (0.45). This is caused by the fact that the reservoir capacity is limited. The reliability of the public water supply decreases dramatically but this can be improved by applying different operation rules.
- **Strategy 5** (decrease in irrigation area to 21,000 ha). As expected the agricultural production will drop but the reliability of the supply increases substantially which will be good for the remaining farmers. The ecological conditions improve considerably.

Besides these five strategies also the impacts have been calculated of a strong decrease of available water from Afghanistan (scenario 2). This is only done for the base case (present situation). From Table 2 it becomes clear that such scenario will have disastrous effects for the agricultural activities in the Sistan delta and for the Hamouns.

It is noted, that the effects of an increase of the demand in Afghanistan is much more than a similar kind of increase in Iran. This is due to the fact that a development in Iran will mainly influence the Hamoun-e-Hirmand, leaving the two other larger Hamouns (Hamoun-e-Puzak and Hamoun-e-Saberi) intact. Developments in Afghanistan will influence all three Hamouns and will result in a nearly complete collapse of the ecology of the Hamouns.

The above results should be considered with great care, in particular the conclusions with respect to the Hamoun-related effects. At the other hand, the calculated impacts seem reasonable and can be used to support the decision making process. Basically the following overall conclusions can be drawn:

- The use of water for irrigated agriculture is mainly restricted by the variability of the supply and not by the total supply.
- This makes sustainable irrigation of the present 120,000 ha in the Sistan Delta only possible if use can be made of the storage capacity of the Chahnimeh reservoirs for

- irrigation water also. Only in that case can a sufficient and reliable supply be guaranteed, which is needed for economically sound agricultural practices.
- Further increase of the irrigation area without the use of the Chahnimeh reservoirs does not make sense at all. Even if use can be made of the Chahnimeh reservoirs the reliability of the supply will be too low to sustain normal irrigated agriculture.
  - There is a direct relation between the use of water for irrigated agriculture and the environmental conditions in the area. Water consumed by agriculture will not be available anymore for the wetlands, resulting in a lower average water cover and corresponding impacts on ecology and health. Effluent water from the agricultural area poses a water quality related risk, but the discussion of this aspect is beyond the goals of this paper.
  - Developments in the upstream areas can have disastrous impacts for the downstream areas. The Chahnimeh reservoirs will take care that the public water supply will not be endangered but the availability of water for irrigation will substantially decrease and the average area of the Hamouns will be much smaller. The frequency of a complete drying out of the Hamouns as happened in the period 2000–2005 will increase with all related problems for ecology and health (sandstorms).
  - Developing the basin and the delta while at the same time protecting the Hamouns requires an intensive cooperation between Afghanistan and Iran.

## Discussion

The main aim of the study was to support the Iranian government in their decision making about the further development of the Sistan Delta. The geo-political situation requires that assumptions have to be made on the possible supply from Afghanistan both with respect to the natural physical aspects (rainfall-runoff) as well as the potential developments upstream (reservoirs, irrigation development). Further water consumption in the upstream areas endanger the downstream irrigation and ecological systems.

Remote sensing techniques have proven to provide valuable information for making such assumptions. If the boundary conditions from Afghanistan are considered to be fixed, the real issue for the decision makers in Iran is then to balance the benefits from irrigated agriculture (production, employment) against the loss in ecological and socioeconomic values of the reduced wetlands and related health hazards for the population. The analysis approach and tools developed in this study provide the quantitative information to support the balancing of interests. The ultimate choice is a political one.

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